THE WASTE OF WATER IN DETROIT[1]

By George H. Fenkell[2]

The information that has been gathered on the consumption and waste of water in Detroit is of interest for several reasons.

1. A water works system was installed in Detroit nearly one hundred years ago, and pipes laid eighty years ago are still in service.

2. Ninety-eight per cent of all active service connections are now metered.

3. A pitometer survey covering the entire city is nearing completion.

4. As Detroit is served with a direct pressure system, hourly records of consumption are available.

5. Detroit is the largest city in population in the United States, and the writer believes in the world, having nearly all of its connections metered.

6. As the quantity of water available from wells has been negligible, the people of Detroit have been at all times compelled to obtain their entire supply for domestic purposes from the distribution system of the water works.

Definition. No small part of the difference of opinion that obtains among those interested in water works affairs is due to the different ideas that prevail regarding the meaning of the verb "waste." From books of reference, the writer learns that to waste means to expend without adequate return; spend uselessly, vainly or foolishly; employ or use lavishly, prodigally, improvidently, or carelessly; cause to be lost through neglect. In spite of the fact that this definition of a simple word is easy to understand, there is lack of accord in its use. As evidence of this, some consumers believe that so long as they are paying for water by meter measurement, the use or misuse of the water concerns no one but themselves. Other users will agree that water escaping from a leaking fixture is waste, even when the supply is metered, but believe circumstances may make legit-

[1] Read before the Cleveland Convention, June 7, 1921. Discussion is invited and should be sent to the Editor.

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imate the opening of a pen stock in extreme weather to prevent pipes from freezing.

Description and history. The City of Detroit is located on the north and west side of the Detroit River on land very uniform in contour, the highest point within its limits being 65 feet above the surface of the river. The water system was installed by a private company in 1827, and in 1836 this was purchased by the city. When Detroit was but a hamlet, the settlers were unable to secure water from wells and were compelled to obtain their supply from the Detroit River, because of the nature of the material underlying Detroit and vicinity. This deposit has a thickness in Detroit of over 100 feet, and is composed of a compact bluish and unstratified clay charged with pebbles and boulders, of glacial origin, and generally impervious to the flow of water.

Beginning with the first government census, the population of the city has increased steadily as follows: 1810, 707; 1820, 1442; 1830, 2222; 1840, 9192; 1850, 21,019. From 1850 to the present, the population is shown graphically on figure 1, and estimates recently made place the population at 1,020,700.

While the use of the pipe laid prior to 1853 has been discontinued, there still remains some that has been in service eighty years or more, as for example, a section of the 10-inch cast iron pipe in Jefferson avenue, laid in 1839. In 1861, or sixty years ago, the distribution system contained 39 miles of cast iron pipe, and it is estimated that about one-half of this is now in use. At present the distribution system contains 1480 miles of cast iron pipe in sizes from 4 inches to 48 inches in diameter, and 3 miles of 48 inch steel pipe.

In 1886 the use of a reservoir was discontinued, and since that date the system has been operated as a direct pressure system. The first Venturi meter was set in a discharge main in 1902, and since 1913 all water pumped has been metered at the pumping station, and before 1913 allowance was made for pump slippage. The service connections are of lead and cast iron.

Systematic metering was begun in 1889, when 194 meters were installed, and by the end of 1890 this number was increased to 856. The accompanying chart shows that approximately 10 per cent of all services were metered by 1897, and this ratio of the number of meters to the number of service connections continued fairly steady until 1912.

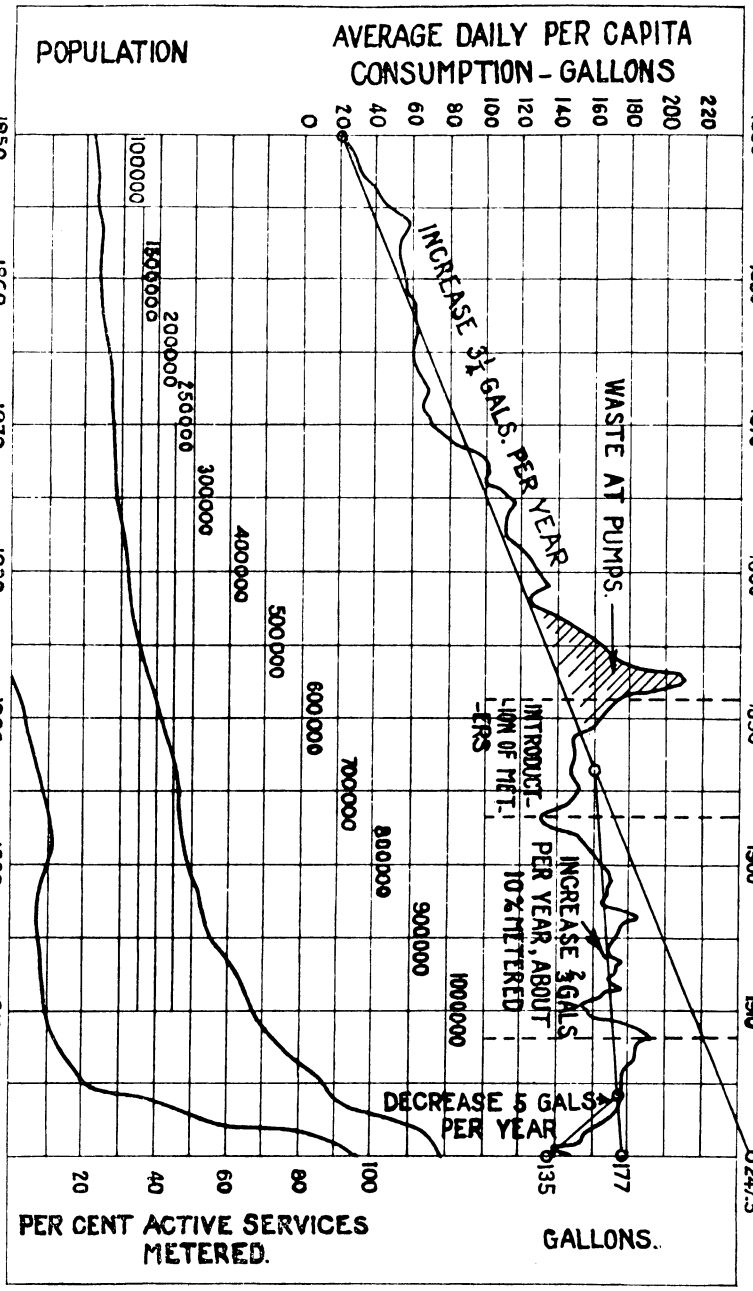

FIG. 1. POPULATION AND WATER CONSUMPTION CURVES

It will be seen by referring to chart 1 that in 1882 the per capita consumption was 120 gallons per day and in 1887 was 209. This phenomenal increase occasioned much discussion for several years. The marked decrease from 1887 to 1891 was due to at least three causes, to wit: the use of meters, which were at the time credited with all of the saving, although the number set was small; careful inspection of premises; and the installation of by-passes on the vertical compound double acting pumps. The introduction of these by-passes permitted the capacity of the two 24,000,000 gallon pumps to be changed at will to 12,000,000 gallon pumps. The by-passes made it possible to eliminate the waste of large quantities of water which were allowed to flow into the suction wells at times when the capacity of these pumps working at minimum speed was greater than needed to supply the city.

In Detroit, general metering was begun in 1913, and on July 1, 1920, 97.4 per cent of all active service connections were covered. The greatest number of meters set in any month was 5345 in October, 1918.

The average water pressure as determined from 39 pressure gauges generally located in fire engine houses, in various parts of the city and read hourly is 31.5 pounds, the maximum pressure is 45 pounds, and the minimum pressure is 22 pounds.

Consumption and waste. The items that enter here may be divided and classified in various ways. A table has been prepared in the way that was most convenient for use in collecting the data, and the following explanations and remarks relate to this table.

In computing the quantities based on meter measurement, an allowance of 5 per cent has been made for under-registration of meters.

The first item covers 131,692 metered domestic accounts. This number was arrived at by subtracting the number of commercial accounts, as estimated from a careful examination of the city directory, from the total number of metered accounts where meters were $1\frac{1}{2}$ inch or smaller.

The water furnished 2985 domestic flat rate accounts is estimated by allowing one thousand gallons for every five cents of revenue. The meter rate in force is on a quantity basis and is $1.00 for the first 1000 cubic feet, 50 cents per thousand for the next 3000 cubic feet, and 35 cents per thousand for all additional.

On the 30th of last June, there were 164,779 service connections of all sizes in the city, and of these 145,053 were in use. On May 1, 1921, it was estimated that the area covered by the water waste survey contained about four-fifths of the total population of the city. The total number of service leaks found by this survey in this area was 447, wasting 4,359,000 gallons per day, or approximately 10,000 gallons for each service per day. All of the water wasted by the service leaks just mentioned was unmetered. By pitometer measurement 116 of these were found to be wasting 2,704,000 gallons per day, or about 23,300 gallons each. The remaining 331 were small service leaks which were located in connection with the inspection of the houses for leaks and are estimated to have averaged 5000 gallons per day each.

The population of Detroit in 1920 as determined by the United States census was 993,739, and at present it somewhat exceeds one million. For the purpose of this paper, a population of one million has been used, and it is believed that no serious error has been introduced by the use of this figure.

All services having meters 2 inches or larger are considered to supply factories and other commercial users, 1219 in all. This number includes some large apartment houses, but it is believed that the error introduced is small.

The number of stores and other commercial accounts, estimated at 7416, was arrived at by an examination of the city directory as previously explained. The water used for building purposes is found by allowing 1000 gallons for every 5 cents revenue in the same manner as with the domestic flat rate accounts.

All water supplied to villages and factories outside the city limits is metered and the number of domestic consumers so supplied is negligible.

The estimate of the total amount of water furnished for municipal purposes is 17.44 gallons per capita per day, or 12 per cent of the total pumpage, or 13 per cent of the total quantity of water consumed within the city limits. Included in this is 0.39 gallons furnished free to charitable institutions and 0.95 gallons at one-half rate to other charitable institutions. The Department of Water Supply receives no revenue for 12 per cent of the water supplied the city. Flooding trenches is credited with 7 cubic feet per lineal foot for 200 miles of trench. The estimates for paving, sprinkling, and flushing streets, and for flushing sewers are based on data furnished

by the Department of Public Works. Four of the 42 engine houses are metered. The water used in 15 ladder houses is estimated. Five of the 11 police buildings are metered, and the supply for 5 parks, including Belle Isle, is metered. There are 12 unmetered park fountains, and the Pitometer Company found the average daily consumption for each of these to be 45,000 gallons. There are 150 continuous flow sanitary drinking fountains on the streets of the city, each of which is estimated to use 1100 gallons per day, and 150 horse fountains, each using, as determined by measurement, 18,000 gallons a day.

The Public Welfare Commission during the winter months makes use of eight skating ponds, and it is estimated that each has a capacity of 20,000 cubic feet, and that it is filled four times a season. All of the 14 public libraries are metered, 123 of the 161 public schools are metered, and the water used in 75 private schools is estimated. Of 35 other public buildings, 8 are metered. There are 32 charitable institutions receiving free water, and 30 on a half rate basis, all of which are metered.

A careful estimate shows that 30,644,000 gallons of water were used in extinguishing fires during the year ending June 30th, 1917, and it has been assumed in preparing this estimate that there has been an increase of 40 per cent since that time in the use of water for this purpose.

Up to May 1, 1921, the Pitometer Company has located, uncovered and stopped leaks in mains amounting to 2,533,000 gallons per day. During the past year there were 75 breaks in mains, and it is estimated that this loss amounted to 32,000,000 gallons. Of these broken mains, 5 were 24 inches in diameter or larger. Great care has been used by the department in laying large mains, and the following test is mentioned to show the result of careful workmanship and good inspection. In 1909 a section of 48-inch cast iron pipe 14,907 feet long, containing thirteen hundred and sixty 48-inch joints, seven 42-inch joints, two 36-inch joints, and thirty-eight 12-inch joints was tested after closing two 48-inch, one 42-inch, one 36-inch, and fifteen 12-inch valves, by supplying the entire line through a 1-inch meter for a period of 20 hours, and the quantity so supplied amounted to 690 cubic feet which was at the rate of 258 gallons per hour.

The quantity used for flushing mains includes that used for filling new mains and making blow-offs of dead ends, and is estimated to be 500 gallons per minute through the year.

The consumption figures given in table 1 are derived from meter measurements.

The figures in the preceding table have been presented without attempting to have the amount accounted for equal the total consumption. It is known that considerable amounts are used that are not included in the table. For example: extinguishing fires in coal piles; use in Water Works Park not included in other parks; street sprinkling wagons operated in business districts; and sprinkling street car tracks by street railway.

Some of the difference can also be accounted for because of the industrial depression during the past few months, for the consumption in September last was 159 gallons, while in March it was reduced to 131. This affects the table, because the metered consumption for any particular month as determined by meter readings taken throughout the city includes water actually used two to five months previously, while the Venturi meters at the pumping station determine the consumption from day to day.

Domestic consumption. According to estimates presented, the daily per capita consumption for domestic use is 56.05 gallons, and an attempt will be made to analyze these figures, by separating this quantity into several items.

It is difficult to determine the domestic requirements by actual measurement, although attempts have been made by the Pitometer Company.

In the survey covering the period from September, 1919, to May, 1921, an examination was made of all properties where evidence seemed to show a waste. In only 50 cases was water found running to prevent freezing, amounting to 101,632 gallons per day. As this survey continued through all seasons of the year and only covered a small area during the season of frost, only a small part of the waste to prevent freezing was detected. The amount of such waste naturally depends upon the temperature, beginning at 32°F. early in the winter and 40°F. late in the winter, increasing rapidly as the temperature drops below these points.

Industrial depression during the winter of 1920–1921 reduced the consumption of water, particularly for manufacturing and railroad purposes, to such an extent, and the mildness of the winter reduced the need for putting into effect anti-freezing methods to such a degree, that the consumption tables give little information on which to base estimates of the quantity of water used to prevent the freez-

TABLE 1

The consumption of water in Detroit	*Gallons per capita per day*	
Domestic		
131,692 Metered accounts	46.48	
2,985 Flat rate accounts	4.23	
Service connection leaks	5.45	56.16
Commercial		
1,219 Industrial plants and railroads	42.77	
7,416 Accounts—Stores, etc	6.42	
Building construction	0.21	49.40
Villages and outside territory		
25 Accounts—Villages	9.62	
14 Accounts—Factories	3.53	13.15
Municipal		
Flooding trenches	0.16	
Paving	0.27	
Sprinkling and flushing streets	0.53	
Flushing sewers	0.02	
42 Engine houses	0.05	
15 Ladder houses	0.03	
11 Police buildings	0.11	
38 Parks and boulevards	7.23	
12 Park fountains	0.56	
300 Drinking fountains	2.87	
8 Skating ponds	0.01	
14 Public libraries	0.01	
161 Public schools	3.01	
75 Private schools	0.55	
35 Public buildings	0.67	
62 Charitable institutions		
32 Free	0.39	
30 Half rate	0.95	
Fires	0.12	17.44
Water works		
Leaks in mains	3.26	
Flushing mains	0.72	3.98
		140.14
Unaccounted for		4.36
Average per capita consumption per day determined by Venturi meter measurement July 1, 1920, to April 30, 1921		144.50

ing of plumbing. It has been found by measurement that the average waste from one tap to prevent freezing is 2000 gallons per day. When one tap in 100 is allowed to flow for three months, the average daily waste for the year will amount to 0.75 gallons per capita; likewise when one in 50 is allowed to waste, the average is 1.5 gallons; one in 25, the waste is 3 gallons, and one in ten the waste is 7.5 gallons. Before Detroit was metered, this waste could be expected to equal or exceed the last figure, but with meters it will probably exceed 0.75 gallons, and be less than three gallons. Because of the mildness of the winter of 1920–1921 the minimum amount, 0.75 gallons will be used in this estimate.

The summer of 1920 was cool and comparatively little water was used for sprinkling. From an examination of the charts made in connection with the water waste survey, there is but little evidence of an increased flow during the evening hours, and it is not possible from these to make an accurate determination. If it is assumed that two-thirds of the services are used at some time for sprinkling purposes, and that each service is used for one-half hour every second day through a period of three months, the yearly consumption will amount to 1.8 gallons per capita. It seems probable that with all services metered, water for sprinkling will be used at the rate of between 0.9 gallons, and 2.5 gallons per capita, and for the season under consideration the former quantity will be used.

The method of arriving at the estimate of the leaks in service connections, 5.45 gallons, was determined by the water waste survey and was explained on a previous page.

The estimate of 22.33 gallons per capita per day for leakage through defective plumbing fixtures has been made in the following manner (table 2):

In making a study of the use of water for domestic purposes, a considerable amount of data was collected in April of this year in an endeavor to determine the minimum night flow in districts of varying character.

While the results are of a conflicting nature, they are mentioned here as they have a bearing on this subject.

One block in the poor class foreign district was measured, first with a pitometer, and later with a $\frac{5}{8}$ inch disc meter. It was found that the rate from midnight to 5 a.m. on Adelaide St. between St. Anoine and Hastings, population 242, 8 leaking faucets, 9 leaking toilets and 2 other defective fixtures, was 724 gallons per hour and

after making an allowance for leaks in fixtures, this was reduced to 339 gallons per hour, which is the equivalent of a net night rate per capita of 33.6 gallons for this block.

The consumption of water in two high class residence streets was measured as follows: Boston Boulevard between Woodward and Third Streets, population 83, 12 service connections, 3 premises equipped with Brooks lawn sprinkling system, with a total of 1120

TABLE 2

Estimate of the daily per capita consumption of water used at night rate for public purposes

	GALLONS PER DAY PER CAPITA	GALLONS PER DAY PER CAPITA AT NIGHT RATE
Municipal		
Flooding trenches	0.16	0.00
Paving	0.27	0.00
Sprinkling and flushing streets	0.53	0.53
Flushing sewers	0.02	0.00
Engine houses	0.05	0.025
Ladder houses	0.03	0.015
Police buildings	0.11	0.11
Parks and boulevards	7.22	4.00
Park fountains	0.56	0.56
Drinking fountains	2.87	2.87
Public libraries	0.01	0.00
Public schools	3.01	1.00
Private schools	0.54	0.18
Public buildings	0.67	0.50
Charitable institutions	1.33	1.00
Fires	0.12	0.12
Skating ponds	0.01	0.01
	17.41	10.92

spray nozzles. This block when measured with a $\frac{3}{4}$ inch disc meter from midnight to 5 a.m. gave a night flow at the rate of 64.4 gallons per capita per 24 hours. No opportunity was given for the inspection of premises. The north side of Chicago Boulevard between Woodward Avenue and Third Street with 14 services supplying 83 people under the same condition gave a per capita of 37.2 gallons.

The night consumption in one high class apartment house, Sherbrook Apartments, was successfully measured from midnight to

5 a.m., 18 people, 6 apartments, 44 faucets and 14 toilets, 15½ per cent of the plumbing fixtures leaking, minimum consumption at the rate of 49.9 gallons per capita per day based on the night rate. Measurements were made on two other high class apartments, but as it was found impossible to determine the population and inspect the plumbing, the results are omitted here.

Readings were taken in three better class apartment houses from midnight to 5 a.m. The Renaud Apartment, main building and annex, and the Touraine Apartments, 52 suites, 220 people, 320 faucets of which 19 were leaking, 53 toilets of which 9 were leaking, gave a gross per capita consumption of 19.25 gallons per day, and when corrected for leaks 17.20 gallons per day.

This information on the minimum night domestic consumption is meagre and conflicting, and any conclusions drawn from it must be in error to some extent. The amount used in these estimates, 22 gallons per capita, is probably a fair average for Detroit.

	Gallons per capita
Manufacturing night consumption, metered, covering district including 80 per cent of the population	19.82
Underground leakage, measured, covering same district	8.91
Underground leakage, not measured, 650 miles of mains at 3000 gallons per mile	2.44
Public night use, estimated	10.92
Night domestic use, estimated	22.00
Total consumption accounted for	64.09

The minimum night rate furnished 80 per cent of the city as measured by pitometer, was 86.42 gallons, and the difference between this amount and the 64.09 gallons accounted for is 22.33 gallons.

In an endeavor to secure data on fixture leakage, an examination of the waste water survey records was made, and of all of the leaking fixtures examined, the inspector reported the flow for 4,336. The waste was metered in 90 per cent of these, and the balance estimated. The waste amounted to 4,238,196 gallons, or at the rate of 977 gallons per leaky fixture, with 80 per cent of the population included in the district surveyed, 17,597 leaking fixtures were discovered, which, at 977 gallons, accounts for 17,192,269 gallons per day. This is probably 10 per cent below actual leakage, for in many blocks where the night consumption was reasonable, no house inspection was made.

When the quantity just mentioned is increased 10 per cent, the leaking fixture waste as determined in this way, amounts to 23.64 gallons per capita, which checks the 22.33 gallons mentioned above.

No way has been found to closely estimate the amount of water lost through domestic carelessness. It is known that hose is allowed to run all summer when families are out of the city, that laundry tub fixtures are frequently kept open for long periods, and that scarcely a day passes but one member of each family allows water to waste needlessly for a few moments, and that in other ways considerable quantities of water are wasted through carelessness. In order to complete this estimate, it will be assumed that each of the 150,000 connections be allowed to waste for 5 minutes each day at the daily rate of 3000 gallons, and this is found to amount to 1.5 gallons per capita.

The estimate of daily consumption will now appear as follows:

	Gallons per capita
1. To prevent freezing	0.75
2. Lawn sprinkling	0.90
3. Leaks in service connections	5.45
4. Leaks in fixtures	22.33
5. Carelessness	1.50
Total	30.93

The quantity subtracted from the total domestic consumption leaves 25.23 gallons for domestic use.

Gardner S. Williams, while Civil Engineer to the Board, discussed matters relating to the consumption of water in Detroit in the Michigan Engineers Annual (1895) and in the University of Michigan Engineering Society *Technic* (1897), and concluded that the necessary quantity of water required daily for domestic use to be 21 gallons, nearly, per capita.

Meters. While the use of meters in Detroit is said to date from the year 1888, the report of the department for 1878 contains an item of $2,700.00 (estimated)for "Metre measured water," and in the report of the Board for 1883 the following appears:

> The Board is fully aware of the wanton and unjustifiable waste of water both now and for most of the time the Water Works has been in existence. The waste has been much more of late years, for a far better head of water has been furnished than formerly, which has enabled the wasting class to do an

increased business. Other cities have the same evil; but no remedy has yet been found and may not be until the fertile brain of some man brings out a cheap and reliable meter.

The few meters and indicators installed prior to 1889 had no appreciable effect on consumption. By referring to figure 1, it will be evident that, disregarding the increased pumpage between 1883 and 1890, due to waste at the pumping station, there was a fairly uniform increase in the consumption of water from 1850 to 1893 of 3¼ gallons per capita per year. Because of variations in temperature and precipitation from year to year, and for other reasons, the consumption line has its ups and downs, but its general direction is well represented by a sloping straight line and if continued would have approximated 247.5 gallons. For a few years preceding and following 1890, careful attention was given to house to house inspection, and the effect of this work combined with that of meters and decreased use of water because of an industrial depression, produced a change in the direction of this line.

By 1897, 10 per cent of all services were metered, and this ratio of metered to unmetered connections continued fairly uniform until 1912. During this period from 1893 to 1913 the use of water increased fairly uniformly at the rate of two-thirds gallons per capita per year, and this line produced indicates that, had the policy of metering 10 per cent of the connections continued, the consumption in 1920 would have amounted to about 177 gallons per capita.

About 1914 the work of metering all consumers was begun, and in 1919 the water waste survey was undertaken with the result that there has been a decided decrease in the consumption of water. The line on the chart indicates that from 1916 to 1920 this decrease has amounted to about 5 gallons per capita per year.

Accepting the lines on the chart as reasonable, the consumption in 1920 would have been 248 gallons had no meters been set and had waste been restricted only by house to house inspection; to 177 gallons had the policy of metering 10 per cent of services been continued; and with all connections metered and with the aid of a water waste survey, the consumption may be expected to approximate 135 gallons per capita.

In a direct pressure system the plant must be capable of supplying water at the maximum hourly rate; and thus the effect of metering on the maximum hourly rate becomes of great importance. The

quotient obtained by dividing the maximum hourly pumpage for the year by the average hourly pumpage is given as follows for several years past:

1910	1.73	1916	1.51
1911	1.75	1917	1.55
1912	1.59	1918	1.50
1913	1.75	1919	1.68
1914	1.64	1920	1.55
1915	1.52		

As normal pressures were never maintained during periods of high pumpage previous to the time meters were set in sufficient numbers to lower the pumpage appreciably, it is apparent that the maximum hourly use has been reduced to even a greater extent than the average. That is, while from 1910 to 1914 inclusive, the maximum hourly rate with low pressures exceeded the average by 70 per cent, from 1915 to 1920 inclusive, the maximum hourly rate with presures nearer normal, exceeded the average by 55 per cent. Likewise it can be shown that the increase of the maximum daily consumption over the average daily consumption has been reduced from 44 per cent for the period from 1910 to 1914, to 32 per cent from 1915 to 1920.

Previous to metering to any extent, a strenuous attempt was made to limit waste by house to house inspection, and this work was continued for some years to an ever lessening degree. As metering increased, this inspection work decreased until in 1910 it was negligible. The number of employees required to carry on efficient semi-annual inspection work is but little less than the number needed for quarterly meter reading.

Consumers have looked on metering with favor and there has been no opposition to the movement from any class.

When the water waste survey was undertaken by the Pitometer Company in 1919, that company assumed that this work would result in the location and stoppage of at least 20,000,000 gallons per day. This company based its estimate on a consumption of 150,000,000 gallons per day for a population of 1,000,000 and on the assumption that the metering of all service connections was automatically controlling domestic waste.

The survey up to May 18 has stopped underground leaks from all causes amounting to about 7,000,000 gallons per day. These

leaks have been located in an area containing 80 per cent of the population, covering 70 per cent of the consumption, and including one-half of all the mains in the city. It seems probable that when the survey has been completed 10,000,000 gallons of underground leaks per day will be stopped. This discrepancy between the estimated and actual underground leakage is due to the fact that meters have not eliminated metered leakage through fixtures, although such leakage has been greatly curtailed. The estimated waste existed, but was divided between house waste and underground leaks.

During the last few months a large number of the oldest small meters were removed and tested, and many of the older large meters were tested in place. From this an attempt was made to determine the error in registration, but as the accuracy of a meter that has been in service for some time varies greatly with the flow, it was thought unwise to make use of averages secured from these data. The meters removed included several different makes.

There are several factors that influence the use of water in a city and make it difficult to compare the consumption of one city with another. A chart has been prepared from data published in the January, 1921, issue of the American City, to show that the use of water decreases as the price increases. The water supply and other conditions in these 57 cities, each with a population exceeding 25,000, vary to such a degree that no law or rule can be found, yet the free-hand line drawn on this chart indicates that a relation exists between rates and quantity used (fig. 2).

Not only do pumping station data show that meters have greatly lessened the use of water for lawn sprinkling, but it is evident to the observer, and notwithstanding this decreased use, lawns are not generally less green than formerly, for greensward and shrubbery are often injured by the application of too much water.

The amount of water used is also dependent on: (1) temperature in winter; (2) temperature and precipitation in summer; (3) condition of business, that is, whether good times or hard times prevail; (4) the class of people supplied.

Hot, dry summers increase greatly the demand for water for cooling and sprinkling purposes. During cold winters much water is sometimes used to prevent the freezing of service pipes, but when made necessary by such pipes being too near the surface of the ground, the metering of the connections will force the owners to lower these pipes. The water department has been called on to

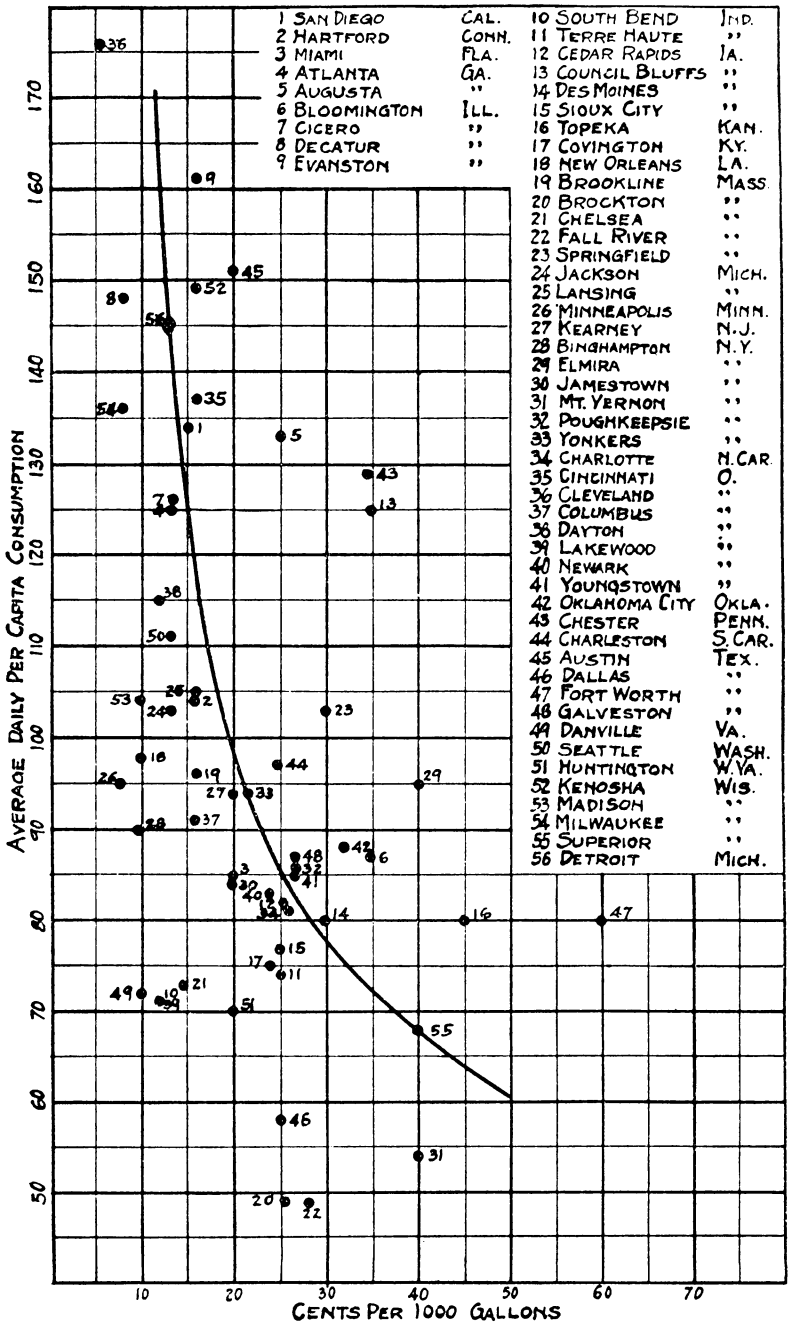

FIG. 2. EFFECT OF COST OF WATER ON DAILY PER CAPITA CONSUMPTION

lower a number of mains, and many services have been relaid because of the information that has been obtained regarding their depth since meters have been used extensively.

Business conditions affect considerably the amount of metered water used for domestic purposes as well as for factories, railways, hotels, stores and other commercial consumers, while the consumption of such unmetered consumers is much less affected. As the amount of water used depends to some extent on the kind or class of people composing a city's population, it may be expected that the per capita consumption for the past few years would from this cause be increased in Detroit, for the percentage of young men liberally reimbursed for their labor has been exceptionally high.

The rule in Detroit has been for domestic consumers to prepare their plumbing for meter, and for the Board to set and maintain the meters without charge or rental. While the department regulations require meters to be set horizontally, experiments were made to determine the relative wear of meters when set vertically and horizontally by running meters of seven different makes in test to destruction. The number tested was small, and the results were not conclusive, as the difference was not great.

The effect of metering and the effect of the waste survey as far as it had progressed at the date given is shown graphically on the daily consumption chart in figure 1.

Water waste survey. In May, 1919, the Pitometer Company was employed to conduct a water waste survey of the distribution system of the city. The city was divided into seven sections, and in May, 1921, five of these sections had been completed and about 50 per cent of the sixth section has been surveyed.

The general purpose of this survey was to account for the water supplied to each section; or to reduce the amount by locating and stopping underground leaks in the mains and services. The survey also furnished a check on all industrial consumers for the purpose of discovering unauthorized use of unmetered water, and included a field test of all meters larger than three inches in diameter. Each section was divided into as many districts for individual study as was made convenient by the location and size of the larger mains of the distribution system, and the consumption for a period of 24 hours was obtained by pitometer measurement.

To date 120 districts have been measured and permanent gauging points established in each district for the future control of waste.

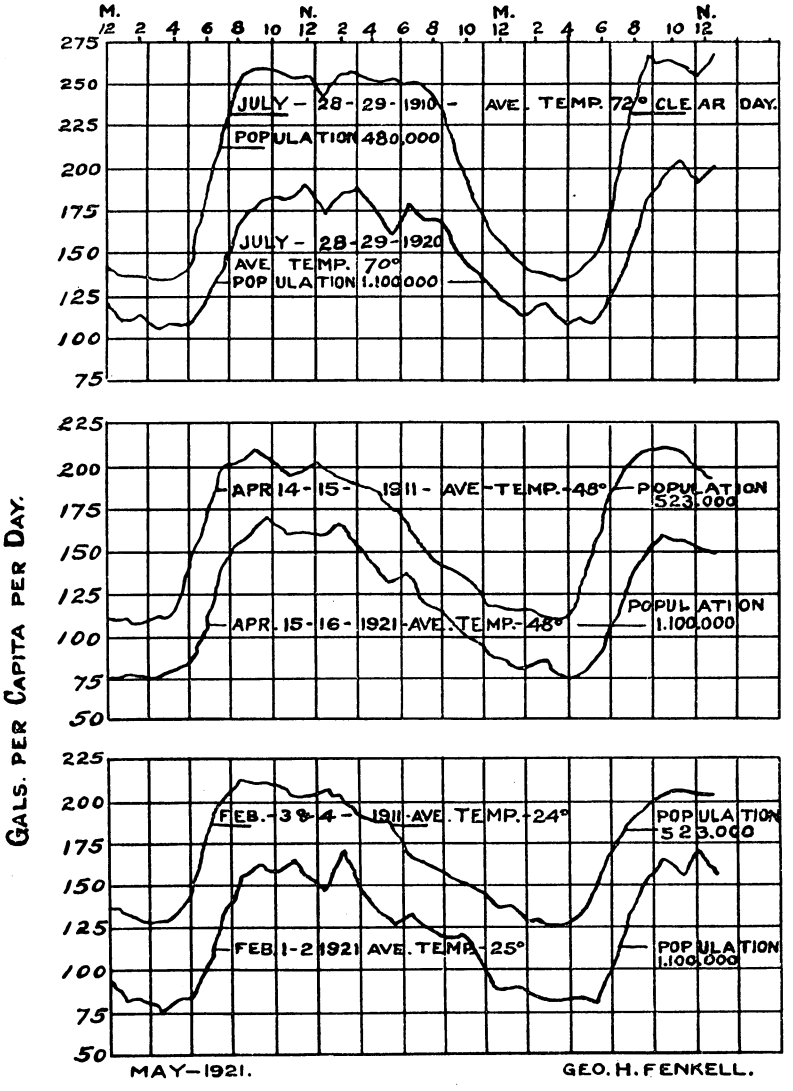

FIG. 3. HOURLY CONSUMPTION OF WATER IN DETROIT—ENTIRE SYSTEM

The area surveyed includes about 80 per cent of the population, and 50 per cent of the miles of main in the entire city distribution system, consuming 106,000,000 gallons per day, or 132 gallons per day per capita. The total minimum night rate in the districts measured amounts to 69,000,000 gallons, or a per capita of 86 gallons per day.

A comparison of the average daily consumption and the minimum night rate in each district gave a comprehensive understanding of underground leakage. To date underground leaks from all causes, amount to approximately 7,000,000 gallons per day, or 9 gallons per capita. Since the city is 98 per cent metered, it was assumed that the house waste had been reduced to a minimum. However, in many instances where the rates of flow were so high as ordinarily to indicate underground leakage, no leaks of the mains or services were found to exist. The necessity of house to house inspection, therefore, became apparent, and the results of these inspections showed that these high rates were caused by leaking plumbing fixtures.

Meters larger than three inches in diameter, to the number of 356, have been tested under field conditions, and in many cases an under-registration has been found. These have been repaired, and in consequence the revenue of the department has been increased. So far there have been no cases discovered of the unauthorized use of water, and this satisfactory condition found in the older, more densely populated portions of the city, may be accounted for in part by the metering of many fire lines and the quite careful inspection of the remaining fire lines.

Leaks in mains and hydrants have been found as follows:

	Gallons per day
4 Broken mains	562,000
12 Joint leaks	861,000
3 Open blow-offs	800,000
2 Blown plugs	190,000
3 Valves with bad stuffing-box leaks	85,000
2 Defective fire hydrants	35,000
	2,533,000
Leaks discovered by the survey include the above and 116 service leaks caused by broken pipes, abandoned services, and blown corporation cocks	2,704,000
331 service leaks estimated at 5000 gallons each	1,655,000
Waste by broken mains, etc	2,533,000
A total of	6,892,000

Caution. In the estimates contained herein, quantities are frequently given to one or two decimal places. It is not the intention to imply from this that the number of gallons of water consumed for various purposes has been determined with great accuracy, for many of the quantities have been found by estimate rather than by measurement. In fact, there is scarcely an item that may not be in error. The reader is also warned against applying the results herein obtained to other cities without giving careful attention to the varying conditions which will be found to exist in Detroit and in the city under consideration.